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Research Development

JANUARY 1987

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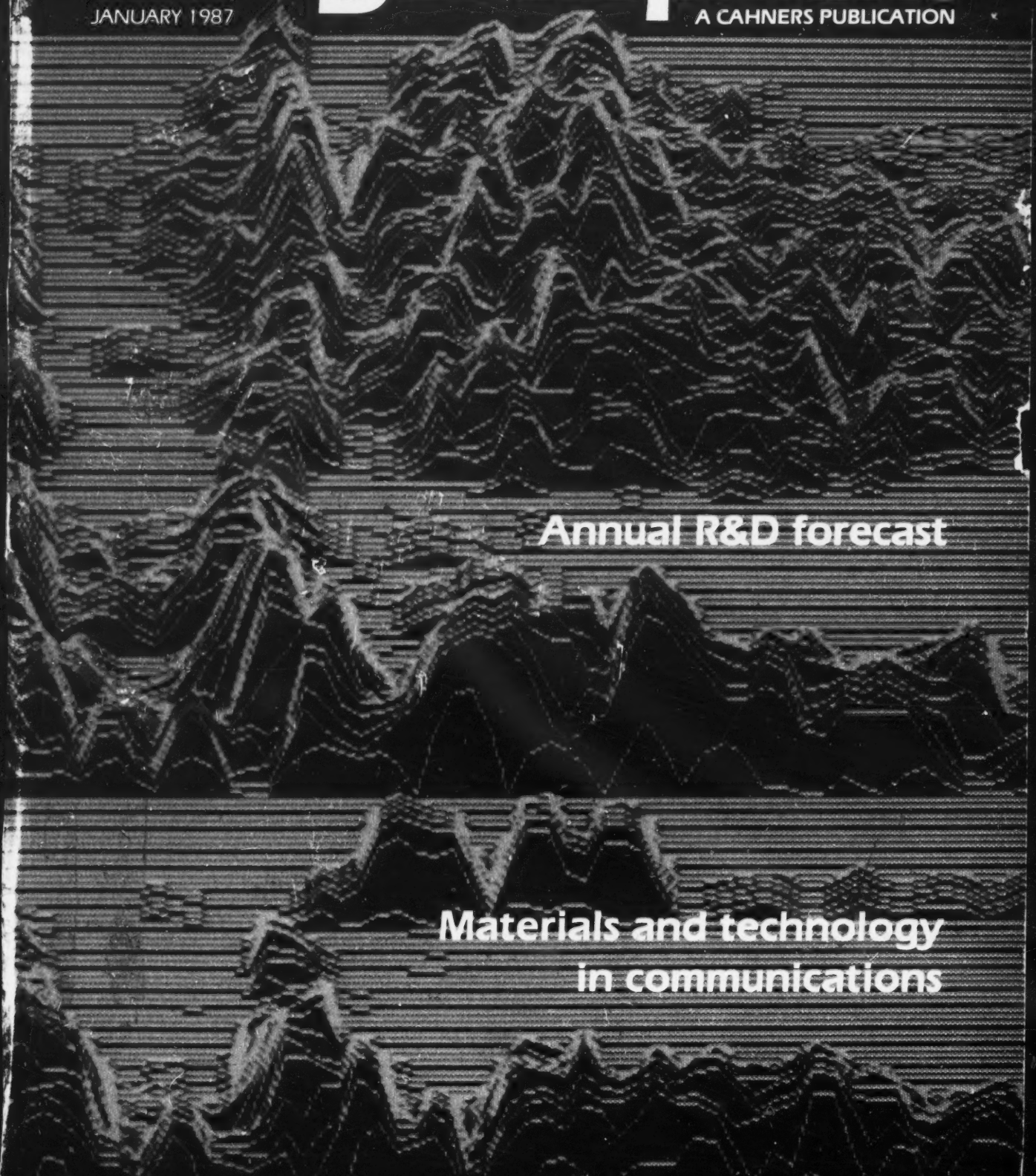

Annual R&D forecast

Materials and technology in communications

SERVING THE $235-BILLION WORLDWIDE R&D INDUSTRY

Research & Development

The magazine with the **IR100 Awards**

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CIRCLE **101** ON INQUIRY CARD

$125 billion for R&D in the USA in 1987

Total funding will increase almost 6%, keeping research and development abreast of growth in the general economy as industry funding increase wanes, and government and other sectors gain shares of total.

C.J. Mosbacher
Consultant, *R&D* magazine

ADD AT LEAST $7 billion to research and development funding for 1987. After consideration of a multiplicity of factors, more than usual, that is what our forecast indicates.

What factors? A new tax law that not only changes tax rates but also changes the ground rules for R&D tax credits and charitable contributions. A Congress that changes Presidentially budgeted priorities in R&D funding. A trend toward more cooperative research and development projects carried out by universities and other nonprofit organizations. And even fewer dollars for R&D in 1986 than we forecast last January, which was offset by even lower inflation than expected.

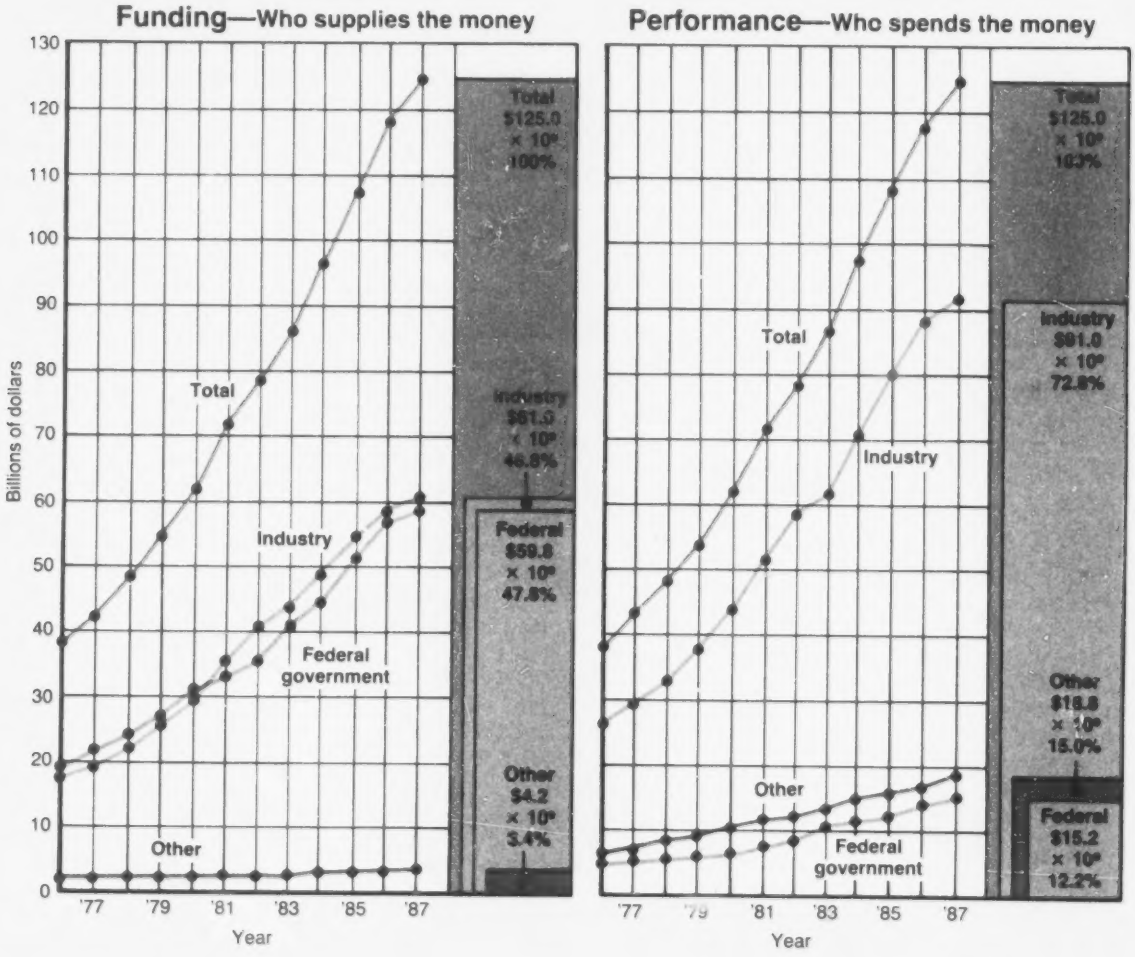
Thus we start with $118 billion instead of $119 billion for 1986 funding. After tracking Federal budgets, Congressional authorizations and appropriations, and actual Federal obligations and expenditures, studying financial reports and other documents from the industrial and other sectors, and speaking with leaders from all sectors, we combined the data to arrive at a projected increase of 5.93% for a total of $125 billion for R&D in calendar 1987.

As can be seen in the graphs accompanying this article, the 1987 total includes $61.0 billion from industry, $59.8 billion from the Federal government, and $4.2 billion from other sources, which include universities, colleges, and other nonprofit organizations. Thus industry is projected to provide 48.8% of 1987 funding, the Federal government 47.8%, and other sources 3.4%.

Considering transfers of funds between sectors, we can project where funds will be spent in the performance of research and development. Our forecast is that industry will use $91.0 billion in 1987, while Federal government laboratories will use $15.2 billion and other sectors $18.8 billion. Thus industry will spend 72.8% of the total dollars available in 1987, the Federal government 12.2%, and other sectors 15.0%.

Lower 1986 dollars

Shortly after our forecast of 1986 R&D funding was prepared, the National Science Foundation pub-



lished its "Science and Technology Data Book" (NSF 85-323), which contained its first estimate of 1986 funding, $122 billion. Included were $58.85 billion of industry funding, $59.25 billion Federal government funding, and $3.9 billion from other sources. That was much higher than our *Research & Development* magazine forecast of $119 billion, which included $58.0 billion of industry funds, $57.2 billion Federal government, and $3.8 billion from other sources.

Subsequently, NSF revised its projections in "National Patterns of Science and Technology Resources 1986" (NSF 86-309), which was dated March 1986 and issued later in the year. Their new projection was for $118.6 billion in 1986 funding. Funding included $59.48 billion from industry, $55.25 billion Federal government, and $3.88 billion other sources. Corresponding amounts for performance of R&D were $87.0 billion by industry, $14.0 billion by Federal government facilities, and $17.6 billion by universities, colleges, and other nonprofit organizations.

As 1986 progressed, it became evident that these NSF data, which were assembled early in the year, would have to be revised on the basis of events that were occurring. While Gramm-Rudman-mandated cuts reduced Federal funding, they were curtailed by a Supreme Court decision. In addition, delays in action on funds for fiscal 1987, which affected fourth quarter 1986, actually increased some funding as Congress adopted continuing resolutions to keep Federally funded activities going. Therefore, in the estimates in our forecast, we used $56.0 billion for Federal funding for 1986.

Conversely, our studies of the industrial sector indicated that, rather than raising industry funding estimates in line with NSF, we would keep our original 1986 forecast projection of $58.0 billion.

As for the academic and nonprofit sector, we raised our estimated 1986 funding $0.1 billion to $3.9 billion. That's how we arrived at the revised total of $118.0 billion for 1986 funding of R&D.

Our results for 1986 performance, as would be expected, also differ from the NSF data. Our estimates

are that industry spent $86.5 billion in 1986, slightly less than the NSF projected, while performance of R&D was $14.0 billion in Federal facilities, agreeing with the NSF data. Our estimate of performance for other sectors was slightly lower than that of NSF at $17.5 billion.

Thus in 1986, industry provided 49.2% of funds for research and development, the Federal government provided 47.5%, and the university and nonprofit sector provided 3.3%. Industry performed 73.3% of the total research and development, Federal facilities performed 11.9%, and universities and nonprofit organizations performed 14.8%.

When these proportions are compared to those indicated earlier for 1987 based on this forecast, a slight shift is seen. Industry's share declines slightly both in funding and performance while the share increases for the other two sectors.

For some time, industry has been increasing its share of funding each year. Its share of performance had been increasing even more as Federal funding moved toward more funding of applied research and development and away from basic research. That meant more Federal dollars going to industry on top of industry's own funding, raising its share of total performance even more. In 1986, a trend toward more basic research funding by the Federal government began. That trend continues.

Whether the slight changes indicated by our forecast comprise a trend away from industrial sector dominance of funding is debatable. Our feeling is that industry funding levels have been hurt by the current economy and may increase considerably if economic expansion goes to higher levels later in 1987 as expected by many economists.

Growth in industry funding slows

Hope for a sudden improvement in the general economy are all well and good, but the fact remains that 1986 was not a great year for American industry. To date, the consensus forecast by economists is for more of the slow growth to continue. Economists who are forecasting increased gross national product expect larger increases toward the end of 1987, with growth averaging about 3% for the year.

Inflation for 1986 was about 2%, and the consensus of economists' forecasts for 1987 at the time this forecast was written was 3.2%. We expect that 1987 inflation will be slightly lower than that; the trend in the consensus over the past few months has been steadily toward lower values.

Thus, we expect the general economy to show an increase of about 6% in 1987, which is just about the same as the 5.93% increase in total R&D funding we are forecasting. If inflation does not increase as the economists expect, R&D funding could gain more than the general economy.

However, industry funding will not quite keep abreast. Our projections indicate an increase of 4.99%. Industry performance, however, will grow some 5.2%.

Confirming this forecast, the NSF issued advanced information dated Nov. 4, 1986. Growth in industry funding during 1987 is projected to grow approximately 5% to nearly $60 billion. While our forecasted funding is higher, the percentage increase is the same. We have confidence in our figure of $61 billion.

The NSF report is based on responses to a mail survey of its Industrial Panel on Science and Technology augmented by interviews with some of its 95 members. "Industry officials said that reasons for the moderate increase include poor sales expectations in durable-goods industries, concerns about short-term profitability, and the need to restructure R&D efforts after corporate mergers," the advanced report said.

"The electrical equipment industry plans the largest average annual increase in R&D expenditures from 1985 to 1987—10%. Among the next five major R&D-performing industries, the increases were as follows: machinery (including computers), 7%; chemicals, 6%; aircraft, 6%; instruments, 5%; and motor vehicles, 4%. The primary-metals industry projected an average annual increases of 5% from 1985 to 1987, and petroleum firms forecast decreases of 11%," the report by NSF said.

Congress changes Federal emphasis

Once again Congress waited until the last minute to pass continuing resolutions to fund the Federal government. In the process, it cut "Star Wars" R&D for the second year. As usual, it increased funds for health research, this time adding $1 billion to the request by the President. That billion caused the increase in Federal funding to go from 5% to 6.79%.

Had Congress acted earlier, more of the fiscal 1987 funds might have been spent in calendar 1986 after the Federal government's fiscal year started on October 1.

More support for academia, nonprofits

Nonprofit organizations and universities will increase their own funding of R&D in 1987 more than the other sectors will on a percentage basis. In actual dollars, however, the increases will be comparatively small. Part of the increase is to compensate for Federal overhead charges being reduced. Another portion is increased contributions caused late in 1986 by changes in how charitable contributions are treated under the new tax law.

Also contributing to these sectors' increases in performance of R&D are increased funding of academic basic research by the Dept. of Defense as mandated by Congress, and increased industrial funding of cooperative R&D programs both in the university and nonprofit sectors.

In summary, we expect R&D funding in 1987 to increase adequately to keep up with the general economy and inflation. If the industrial economy improves more than expected, we could see even higher levels of R&D funding. **R&D**

C.J. Mosbacher has continued as a consultant to *Research & Development* magazine since he retired as Executive Editor on January 1, 1986.

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Research & Development

FEBRUARY 1987

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Pittsburgh Conference issue

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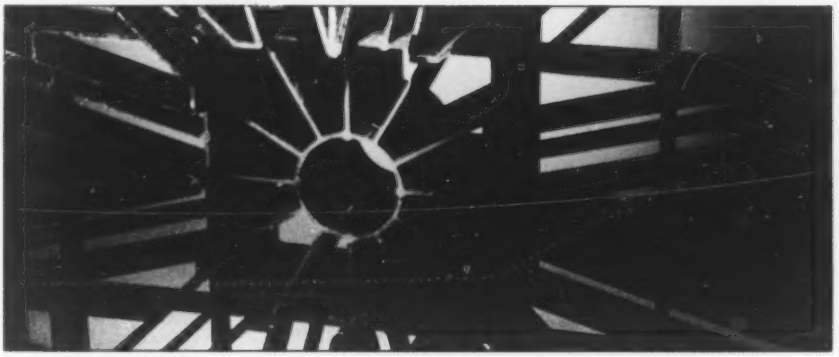
Chemical analysis assures performance. **See p 85.**



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ABOUT THE COVER

A space-age "spiderweb" made of foamable plastic forms the base of a pallet designed for shipping heavy aircraft-engine parts. A team from General Electric's R&D Center, Schenectady, NY, and the Plastics Group, Pittsfield, MA, developed a CAD/CAE software package that was used to produce the design.

To take full advantage of the software, the foamable plastic must be uniform from batch to batch. Chemical analysis of raw materials and finished foamable liquids, as well as mechanical testing of the solidified structural foam, can assure that the manufactured parts will perform as they should every time.

A story about GE's program for the development and design of foamed-plastic parts is on p 85.

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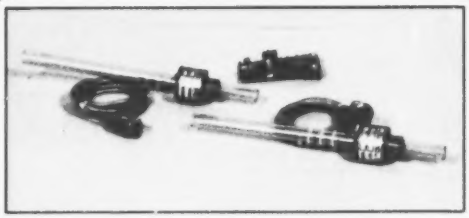

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CIRCLE **306** ON INQUIRY CARD

OPINION POLL RESULTS

Readers ask extensive review of nuclear reactor safety

READERS of this magazine favor an extensive review of nuclear reactor safety before any new reactors are started, if the more than 2,000 who responded to our Opinion Poll survey are typical.

Nearly half of the respondents acknowledged losing some or all of their enthusiasm for nuclear power following the Chernobyl incident.

How close a respondent lives to a nuclear power plant did not seem to affect response patterns except for those living within five miles of a reactor. Their answers appear to reflect a stronger support for nuclear power. Their answers to **No. 1** were: a. 28%, b. 47, c. 6, d. 15, e. 4. To **No. 2**: a. 22%, b. 11, c. 6, d. 61; **No. 4**: a. 28%, b. 65, c. 7; **No. 5**: a. 55%, b. 41, c. 4; **No. 8**: a. 69%, b. 31.

Also, those who don't know how near they live to a nuclear power plant are less aware than others of fail-safe reactor designs, answering **No. 8**: a. 43%, b. 57.

Responses for all respondents follow:

1. *Would you say that* before *the Chernobyl event your feelings about nuclear power made you . . .*
   a. An enthusiast 15% d. A detractor 10%
   b. A supporter 52 e. An opponent 7
   c. Neutral 16
2. *Has what you know about the event at Chernobyl reduced your enthusiasm for nuclear power . . .*
   a. A little 31% c. Completely 5%
   b. A lot 12 d. Not at all 52
3. *Do you believe that this event will have a lasting negative effect on the use of nuclear power?*
   a. Yes 59% b. No 37% c. No opinion 4%
4. *Do you believe that this event will hasten the swing to non-nuclear energy sources?*
   a. Yes 39% b. No 54% c. No opinion 7%
5. *Do you believe that all nations, including the U.S., need extensive review of their nuclear safety provisions before committing to build new reactors?*
   a. Yes 72% b. No 24% c. No opinion 4%
6. *Do you believe that the Chernobyl event will damage Russian credibility in the world?*
   a. Yes 65% b. No 30% c. No opinion 5%
7. *Do you believe that the event will set back the efforts of Mikhail Gorbachev to present Russia as a leading technology nation?*
   a. Yes 59% b. No 33% c. No opinion 8%
8. *Are you aware of the existence of fail-safe reactor designs that would simplify the construction and reduce the costs and hazards associated with nuclear power plants?*
   a. Yes 52% b. No 48%
9. *How close do you live to a nuclear power reactor?*
   a. Within 5 miles 3% d. Within 100 miles 25%
   b. Within 25 miles 18 e. More than 100 miles 21
   c. Within 50 miles 28 f. Don't know 5

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Research & Development

MARCH 1987

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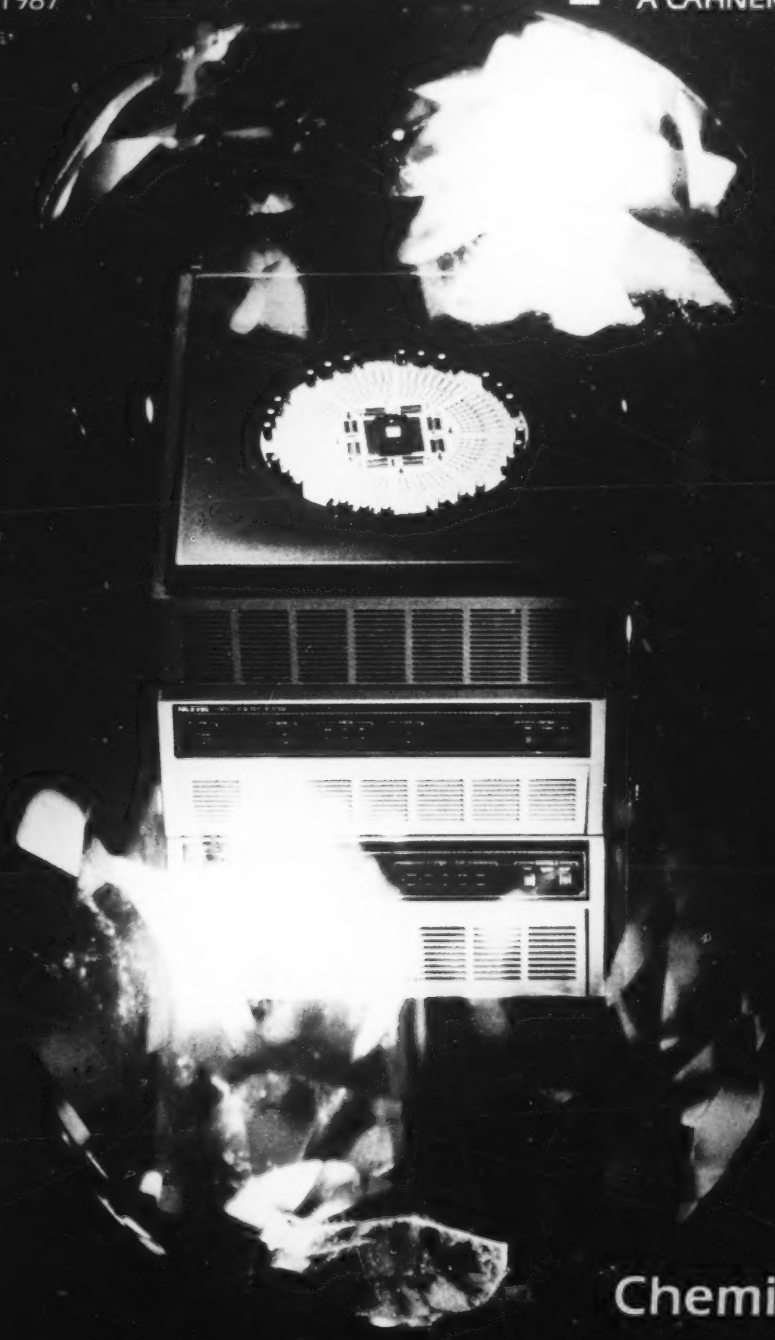

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Verification of VLSI designs needs specialized hardware and software. Highlevel Technology's "Topaz" system offers memory emulation, pod control, and logic analysis. Operator can compare expected with actual results, then make changes.

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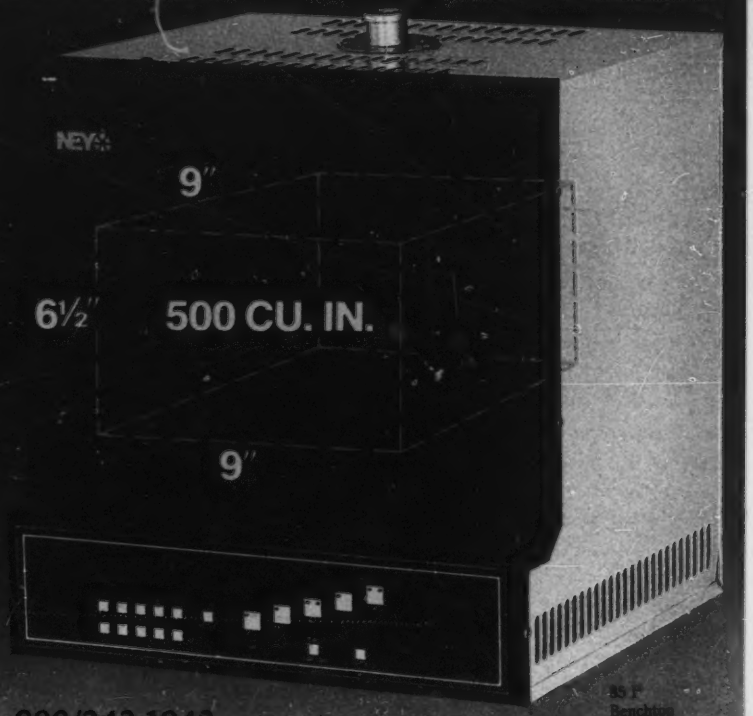

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CIRCLE 101 ON INQUIRY CARD

Salaries are up for workers in R&D in year of changes

Lower inflation rate in U.S. helps scientists and engineers to make real gains in period of small raises; early retirement programs lop off high end of work force and set new directions for long-established industry trends.

Robert R. Jones, Editor

HOW MUCH MONEY are other scientists and engineers your age, with equal experience and education, earning in research and development? How much salary trade-off do you have to accept to get university ambience? What is the salary penalty in research, development, and quality assurance for being female?

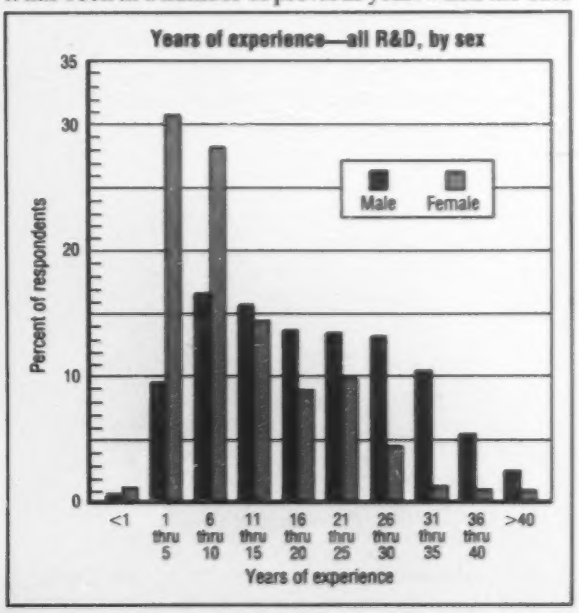
If you want answers to these and other questions that you may have about people who work in research, development, and quality assurance, then read on. You'll find your answers in this annual *Research & Development* magazine profile of the R&D industry. To the extent that nearly 3,500 respondents can be representative of R&D and QA, these data speak for the industry.

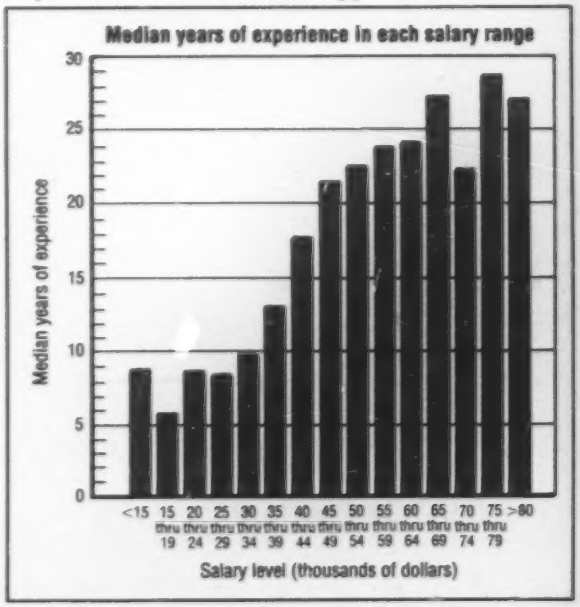
This year's profile is presented in one part, unlike it has been in a number of previous years when the data for the total industry and for individual disciplines were presented in March, and figures for age, experience, workplace, and sex were presented in May.

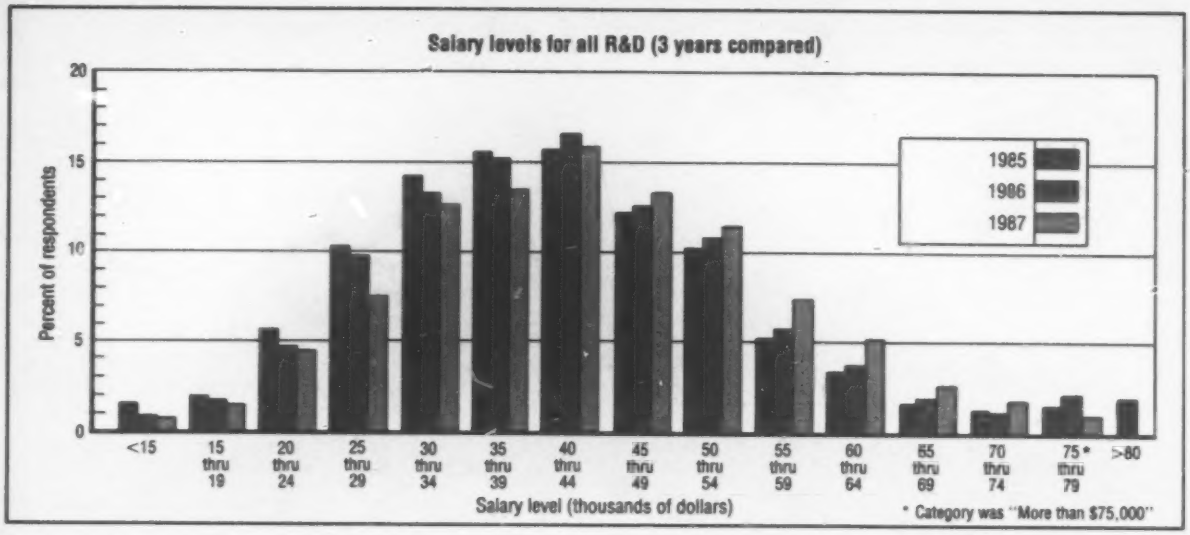
As was mentioned in two previous reports, we made a change in this annual study three years ago, and that change temporarily reduced the comparisons that we could make.

This industry study, which originally was simply a salary survey, was established in years when the top income that could be expected for an R&D scientist or engineer was below $50,000. When we asked readers about their salaries, the possible answers spanned $3,000 increments—$16,000 through $18,000, $19,000 through $21,000, etc. That was quite satisfactory at that time.

As time passed, the lower end of the salary range stayed about the same, but the upper end moved stead-







ily away from it and we added spans in the questionnaire to keep up with it. As a result, our charts in which we presented the data became hopelessly cluttered.

To reduce the clutter, we changed the spans to $5,000 in our study of three years ago, knowing that we would have to forego some meaningful comparisons for several years. Now those years have passed, and we once again can present a chart which shows a 3-year comparison (this year and the two previous) of salary levels for all R&D workers.

As mentioned above, the lower end of the salary range for R&D workers has hardly changed over the years of this study. Now, it appears that change may be occurring at the lower end. Two years ago 1.6% of respondents were in the lowest salary group. Last year it was 0.9%. This year 0.8% report that they are earning less than $15,000 per year.

The upper span on the questionnaire was changed this year to be "$80,000 per year or more." Some 1.8% of respondents are in that new span.

With one out of every 56 R&D workers now earning more than $80,000 per year, it is hard to believe that the upper end of our survey just seven years ago was "$46,000 or more." At that time, the largest single group of the respondents and the median income for all R&D fell into the $25,000 through $27,000 span.

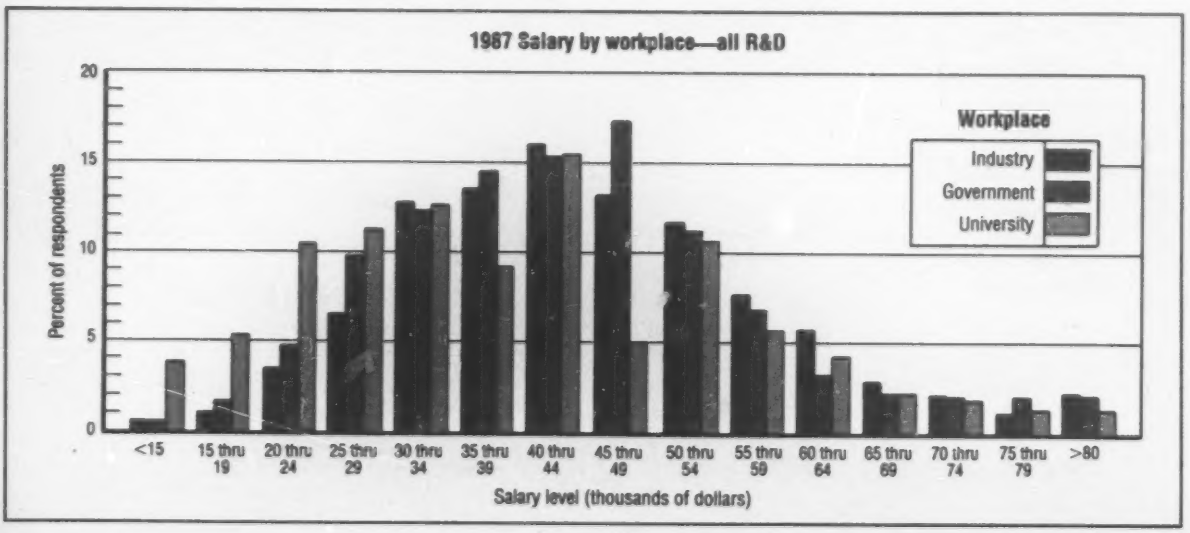
Salary increases are down this year, particularly for men, but also down for women, as we will discuss below. Fortunately we continue to enjoy low inflation, and one result is a substantial increase in income in relation to purchasing power. Increases in the rate of pay for all R&D are reflected in this table.

Increases in rate of pay*

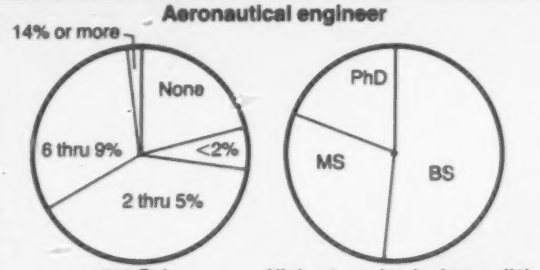
Amount	1987	1986	1985	1984	1983	1982
	% of respondents					
None	16.5	11.3	9.3	16.3	14.7	6.3
Less than 2%	4.3	3.6	2.9	2.1	1.9	1.2
2 through 5%	39.2	37.1	36.6	26.9	15.9	10.6
6 through 9%	30.8	36.3	37.6	38.9	34.2	34.5
10 through 13%	6.0	8.3	10.1	11.5	25.1	34.0
14% or more	3.2	3.3	3.6	4.4	8.3	13.3
Ahead of inflation	79.2	60.1	63.3	54.8	33.4	47.3

*Granted in preceding year for year shown

It is interesting to see how lower inflation has affected the question of salary increases. In the above ta-



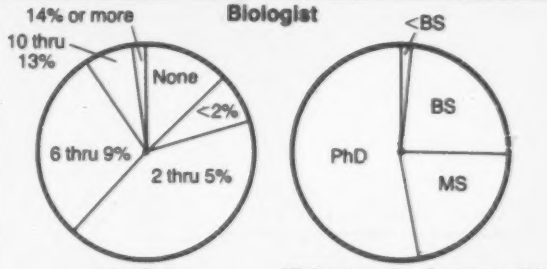
Aeronautical engineer



1986 Raise — Highest academic degree (%)

1986 salary range:	<$15,000 = 0.0% >$80,000 = 2.0%	Median $50,278
Years with present employer:	< 1 yr = 2.0% > 36 yr = 2.0%	Median 13.0 yr
Age of respondents:	<26 yr = 2.0% >65 yr = 10.2%	Median 51.25 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 10.2%	Median 23.56 yr

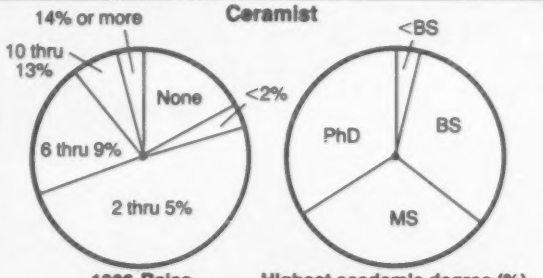
Biologist



1986 Raise — Highest academic degree (%)

1986 salary range:	<$15,000 = 0.6% >$80,000 = 1.7%	Median $38,100
Years with present employer:	< 1 yr = 2.8% > 36 yr = 0.6%	Median 8.54 yr
Age of respondents:	<26 yr = 2.2% >65 yr = 0.6%	Median 41.11 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 1.1%	Median 14.47 yr

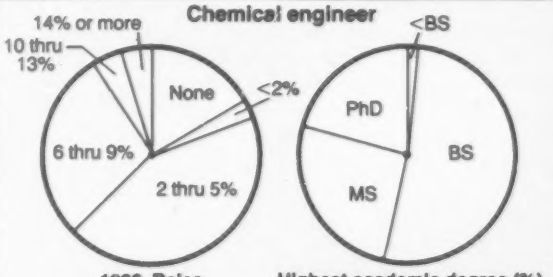
Ceramist



1986 Raise — Highest academic degree (%)

1986 salary range:	<$15,000 = 1.8% >$80,000 = 0.0%	Median $47,812
Years with present employer:	< 1 yr = 1.8% > 36 yr = 0.0%	Median 8.0 yr
Age of respondents:	<26 yr = 1.8% >65 yr = 0.0%	Median 40.27 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	Median 16.89 yr

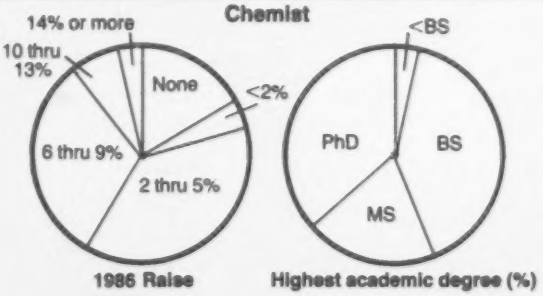
Chemical engineer



1986 Raise — Highest academic degree (%)

1986 salary range:	<$15,000 = 1.7% >$80,000 = 1.7%	Median $45,865
Years with present employer:	< 1 yr = 3.1% > 36 yr = 2.4%	Median 9.38 yr
Age of respondents:	<26 yr = 6.8% >65 yr = 2.0%	Median 41.31 yr
Years of experience:	< 1 yr = 0.3% >40 yr = 2.4%	Median 16.04 yr

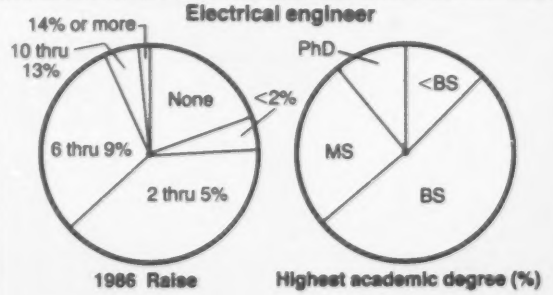
Chemist



1986 Raise — Highest academic degree (%)

1986 salary range:	<$15,000 = 0.8% >$80,000 = 1.5%	Median $41,860
Years with present employer:	< 1 yr = 2.9% > 36 yr = 1.1%	Median 9.46 yr
Age of respondents:	<26 yr = 1.9% >65 yr = 1.1%	Median 41.88 yr
Years of experience:	< 1 yr = 0.4% >40 yr = 1.2%	Median 16.23 yr

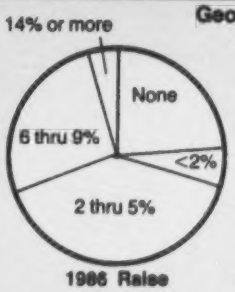
Electrical engineer



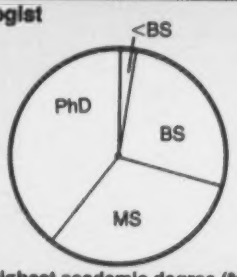
1986 Raise — Highest academic degree (%)

1986 salary range:	<$15,000 = 0.9% >$80,000 = 2.0%	Median $44,308
Years with present employer:	< 1 yr = 4.0% > 36 yr = 1.4%	Median 9.75 yr
Age of respondents:	<26 yr = 2.6% >65 yr = 2.0%	Median 44.58 yr
Years of experience:	< 1 yr = 0.6% >40 yr = 3.2%	Median 20.66 yr

Geologist



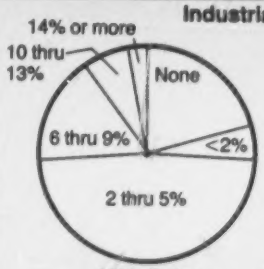
1986 Raise



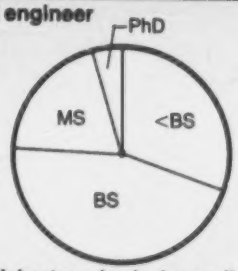
Highest academic degree (%)

1986 salary range:	<$15,000 = 0.0% >$80,000 = 2.6%	Median $45,714
Years with present employer:	< 1 yr = 0.0% > 36 yr = 2.6%	Median 12.5 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	Median 47.17 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 2.6%	Median 22.17 yr

Industrial engineer



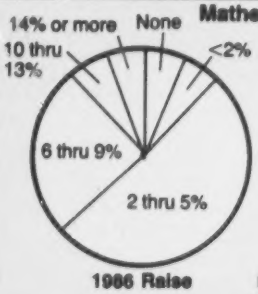
1986 Raise



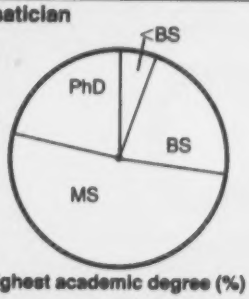
Highest academic degree (%)

1986 salary range:	<$15,000 = 2.4% >$80,000 = 2.4%	Median $38,889
Years with present employer:	< 1 yr = 2.4% > 36 yr = 0.0%	Median 8.64 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	Median 42.17 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	Median 18.0 yr

Mathematician



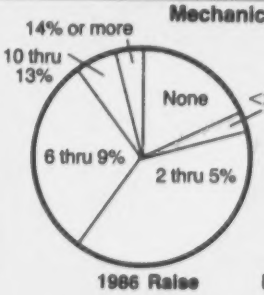
1986 Raise



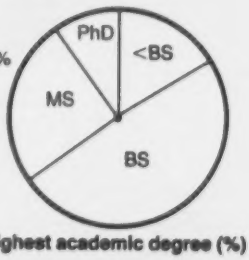
Highest academic degree (%)

1986 salary range:	<$15,000 = 0.0% >$80,000 = 5.3%	Median $46,250
Years with present employer:	< 1 yr = 0.0% > 36 yr = 0.0%	Median 9.12 yr
Age of respondents:	<26 yr = 0.0% >65 yr = 0.0%	Median 49.0 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 0.0%	Median 21.75 yr

Mechanical engineer



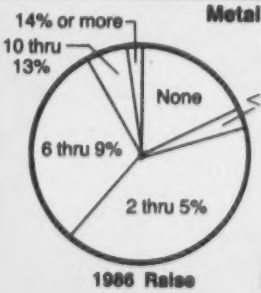
1986 Raise



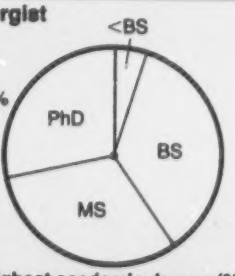
Highest academic degree (%)

1986 salary range:	<$15,000 = 0.2% >$80,000 = 2.0%	Median $44,385
Years with present employer:	< 1 yr = 2.5% > 36 yr = 1.7%	Median 9.45 yr
Age of respondents:	<26 yr = 1.7% >65 yr = 1.7%	Median 45.45 yr
Years of experience:	< 1 yr = 0.5% >40 yr = 4.0%	Median 20.30 yr

Metallurgist



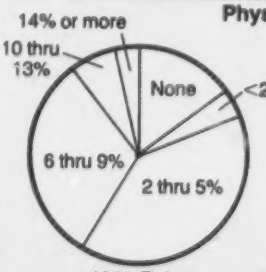
1986 Raise



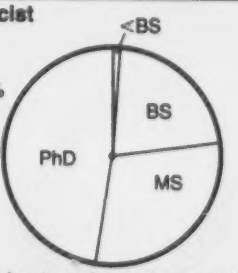
Highest academic degree (%)

1986 salary range:	<$15,000 = 0.0% >$80,000 = 1.8%	Median $46,625
Years with present employer:	< 1 yr = 1.8% > 36 yr = 1.2%	Median 9.08 yr
Age of respondents:	<26 yr = 1.8% >65 yr = 0.6%	Median 43.18 yr
Years of experience:	< 1 yr = 0.0% >40 yr = 1.2%	Median 18.56 yr

Physicist

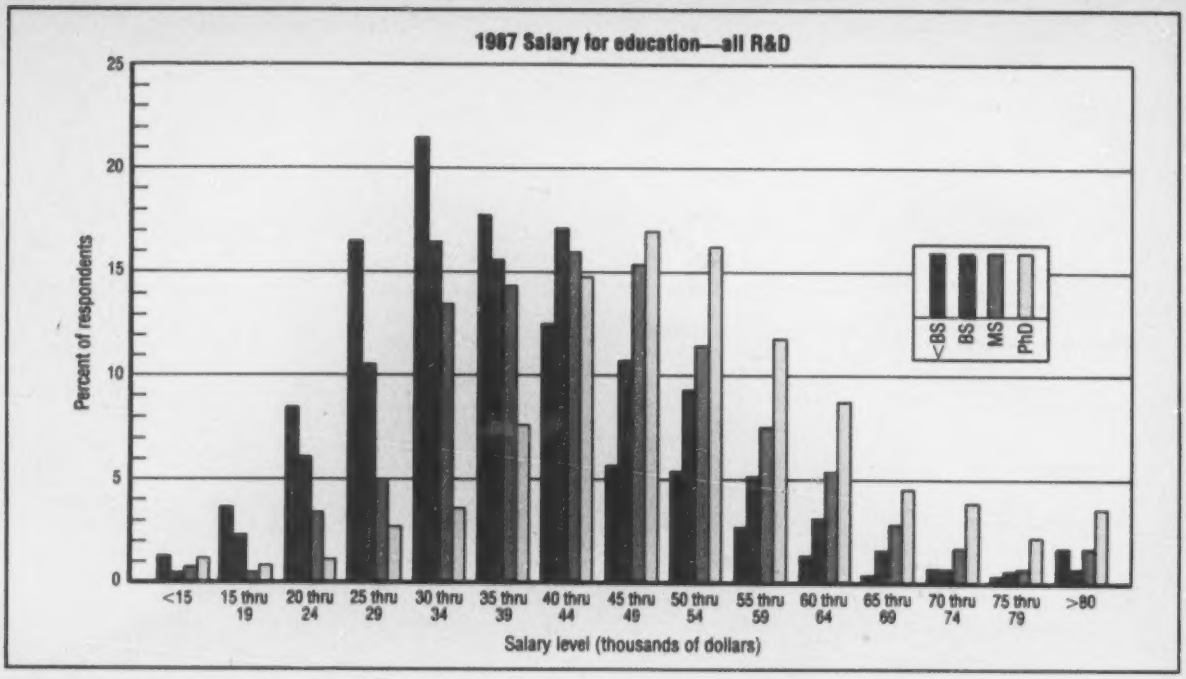


1986 Raise



Highest academic degree (%)

1986 salary range:	<$15,000 = 0.7% >$80,000 = 4.1%	Median $48,431
Years with present employer:	< 1 yr = 3.7% > 36 yr = 1.0%	Median 8.60 yr
Age of respondents:	<26 yr = 1.4% >65 yr = 1.7%	Median 43.45 yr
Years of experience:	< 1 yr = 0.7% >40 yr = 2.4%	Median 18.18 yr



ble we see that in the years of 1982 and 1983, 34% of the respondents received salary increases of 6 through 9%, more than 25% received increases of 10 through 13%, and more than 8% got increases of 14% or more.

Despite those hefty increases in income, fewer than half of the respondents stayed ahead of inflation.

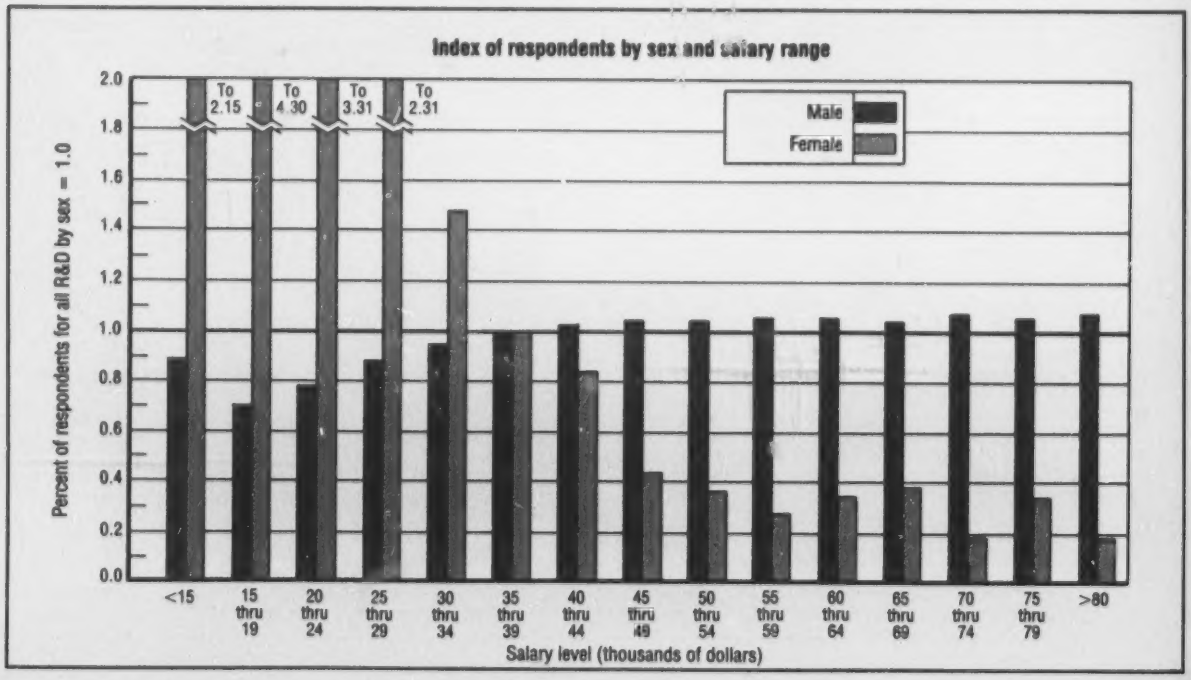
Look at the shift in the figures in the column for 1987; 16.5% got no raise at all! Only 9.2% got more than 9%. Yet 4 out of 5 respondents came out ahead of inflation.

The number receiving no increase at all is up for the second year in a row to the highest level in 6 years. We should remember, of course, that the no-increase group includes a number of new-hires.

The most impressive salary increase by discipline this year was made by the chemists, with 42.3% getting increases of 6% or more per year. Chemists displace ceramists who were in the first position in the two previous years.

Physicists follow the chemists closely with 41.9% getting increases of 6% or more per year. Then come mechanical engineers with 40.1% and biologists with 39.5% getting raises of 6% or more.

Industrial engineers got the short end of the stick this year with only 26.2% receiving raises of 6% or more. They displaced the aeronautical engineers who



were at the bottom last year.

We have pointed in several recent reports to changes which apparently are a result of corporate programs to encourage early retirement of top-level employes. These early retirement programs change the relationships in our tables in ways that we had not seen or anticipated in the past. One consequence of the early retirement programs is larger than usual shifts in the relative positions of median incomes by disciplines.

This may help to explain how, despite being at the bottom for salary increases last year and having a low gain in median salary this year, aeronautical engineers are at the top of the list for median salaries.

Rankings for disciplines by median salaries

Rank 1987	Rank 1986	Discipline	Median salary 1987	Median salary 1986	% increase
1	2	Aero. Engr.	$50,278	$48,181	4.4
2	3	Physicist	48,431	47,426	2.1
3	5	Ceramist	47,812	44,285	7.9
4	1	Metallurgist	46,625	49,166	−5.2
5	6	Mathematician	46,250	44,166	4.7
6	4	Chem. Engr.	45,865	44,619	2.8
7	9	Geologist	45,714	41,136	11.1
8	8	Mech. Engr.	44,385	41,901	5.9
9	7	Elec. Engr.	44,308	43,291	2.4
10	10	Chemist	41,860	40,285	3.9
11	12	Indust. Engr.	36,889	36,666	6.1
12	11	Biologist	38,100	37,013	2.9

The median salary for all respondents in this study is $43,224, up 4.3% from last year's $41,449. (Please note that last year's industry profile was presented in two parts, as mentioned above. The 1986 median salary for all R&D was stated correctly in the March issue, but suffered from a computer glitch and was incorrectly stated in the May issue.)

With only the metallurgists losing ground in median salary in this years's report, and with most disciplines making healthy gains, workers in research, development, and quality assurance exhibit an attractive demographic profile. This group will draw a paycheck in 1987 exceeding $25.9 billion, a figure that is up from last year's $24.5 billion by 5.7%, and that 5.7% is substantially more than last year's inflation.

This affluence can be compared to an annual paycheck for R&D and QA of $18.9 billion just 3 years ago.

The premiums that we have mentioned in previous years for age, experience, and advanced degrees continue this year, and may help to explain why this industry has an impressive record of experience and education.

Premium for experience

In recent years the median age of respondents has moved upward from 40.4 in 1980 to 42.6 this year. Median years of experience of our respondents has increased from 15.8 in 1982 to 17.4 this year. (This is difficult to explain in the light of other changes which seem to be caused by early retirement programs.)

The premium that is paid for experience shows up clearly when salary is related to experience as reported in this study. For this year's respondents with less than one year's experience, the median income was

1987 R&D Industry profile:

1. What is your annual salary?
   - a. Less than $15,000 ..... 0.8%
   - b. $15,000 to $19,999 ..... 1.5
   - c. $20,000 to $24,999 ..... 4.3
   - d. $25,000 to $29,999 ..... 7.5
   - e. $30,000 to $34,999 ..... 12.6
   - f. $35,000 to $39,999 ..... 13.2
   - g. $40,000 to $44,999 ..... 15.8
   - h. $45,000 to $49,999 ..... 13.1
   - i. $50,000 to $54,999 ..... 11.4
   - j. $55,000 to $59,999 ..... 7.4
   - k. $60,000 to $64,999 ..... 5.1
   - m. $65,000 to $69,999 ..... 2.6
   - n. $70,000 to $74,999 ..... 1.8
   - o. $75,000 to $79,999 ..... 1.0
   - p. $80,000 or more 1.8

2. Your raise during the past year was
   - a. None 16.5%
   - b. Less than 2% 4.3
   - c. 2% through 5% 39.2
   - d. 6% through 9% 30.8
   - e. 10% through 13% 6.0
   - f. 14% or more 3.2

3. How long have you worked for your present employer?
   - a. Less than 1 year 3.0%
   - b. 1 through 3 years 17.3
   - c. 4 through 6 years 16.9
   - d. 7 through 9 years 14.0
   - e. 10 through 12 years 9.0
   - f. 13 through 15 years 6.8
   - g. 16 through 18 years 8.0
   - h. 19 through 21 years 6.5
   - i. 22 through 24 years 5.6
   - j. 25 through 27 years 4.1
   - k. 28 through 30 years 3.4
   - m. 31 through 33 years 2.6
   - n. 34 through 36 years 1.3
   - o. More than 36 years 1.3

4. What is your age?
   - a. Under 26 years 2.4%
   - b. 26 through 30 ..... 10.3
   - c. 31 through 35 ..... 15.4
   - d. 36 through 40 ..... 15.5
   - e. 41 through 45 ..... 14.9
   - f. 46 through 50 ..... 12.8
   - g. 51 through 55 ..... 12.2
   - h. 56 through 60 ..... 9.5
   - i. 61 through 65 ..... 5.7
   - j. More than 65 years 1.4

5. How many years of experience do you have?
   - a. Less than one year 0.4%
   - b. 1 through 5 years 11.1
   - c. 6 through 10 years 17.9
   - d. 11 through 15 years 15.4
   - e. 16 through 20 years 13.4
   - f. 21 through 25 years 13.3
   - g. 26 through 30 years 12.3
   - h. 31 through 35 years 9.3
   - i. 36 through 40 years 4.8
   - j. More than 40 years 2.0

6. What is the highest degree you hold?
   - a. Less than bachelor 8.6%
   - b. Bachelor 39.4
   - c. Master 24.0
   - d. Doctorate 28.0

7. What is your profession?
   - a. Chemist 35.0%
   - b. Chemical engineer 8.4
   - c. Mechanical engineer ... 12.5
   - d. Electrical engineer 10.0
   - e. Aeronautical engineer .. 1.4
   - f. Industrial engineer 1.2
   - g. Physicist 8.4
   - h. Metallurgist 4.7
   - i. Biologist 5.2
   - j. Mathematician 0.5
   - k. Ceramist 1.6
   - m. Geologist 1.1
   - n. Other 10.9

8. Do you work in
   - a. Industry 76.6%
   - b. Government 14.2
   - c. University 9.2

9. Are you
   - a. Male 91.7%
   - b. Female 7.2

$27,917. (This is up from $24,375 last year.) For the respondents with 1 through 5 years of experience, the median income is $31,775. For 6 through 10 years' experience, income rises to a median of $36,455.

At the upper end of the scale, those with 36 through 40 years' experience have a median income of $49,773, up from $48,321 last year.

Premium for education

The percentage of respondents having PhDs appears to be one place where the early retirement programs are affecting our results. The percentage with PhDs increased from 27.6 in 1980 to 33.1 in 1985. Last year it was 30.1 and this year the percentage is 28.0, down 7%! One suspects that the top end of the 1985 work force is gone.

Biologists continue to lead the field with the most respondents having PhDs at 52%, down from 54.1% last year. When masters and doctors are considered together and disciplines are ranked for advanced degrees, physicists are in first place with 78.8% having advanced degrees. Biologists are second with 74.3% and mathematicians are a close third at 73.7%.

The declines in numbers notwithstanding, for the typical worker in research, development, and quality assurance, the monetary reward for having a PhD is substantial. Indications from this year's respondents are that there is a career advantage of $1,703,000 for the person having a PhD when compared to a colleague whose formal training stopped at the baccalaureate level.

It is obvious from responses to this survey that the net value of a PhD over a BS depends on an individual's subject matter field, sex, and workplace (government, university, or industry). And, inasmuch as median figures are used to calculate the premiums for education, it is obvious that many individuals with PhDs will reap much larger benefits from their advanced degrees than we show here.

Since 6.8% of our respondents still are on the job after 35 years' experience, we are projecting 35-year careers in this calculation. The $1,703,000 premium for education is what remains from 35 years' income at the higher median income level of PhDs after we adjust for interest earned and deduct for the costs of added tuition and the additional years spent getting the advanced degree rather than earning income from full-time work.

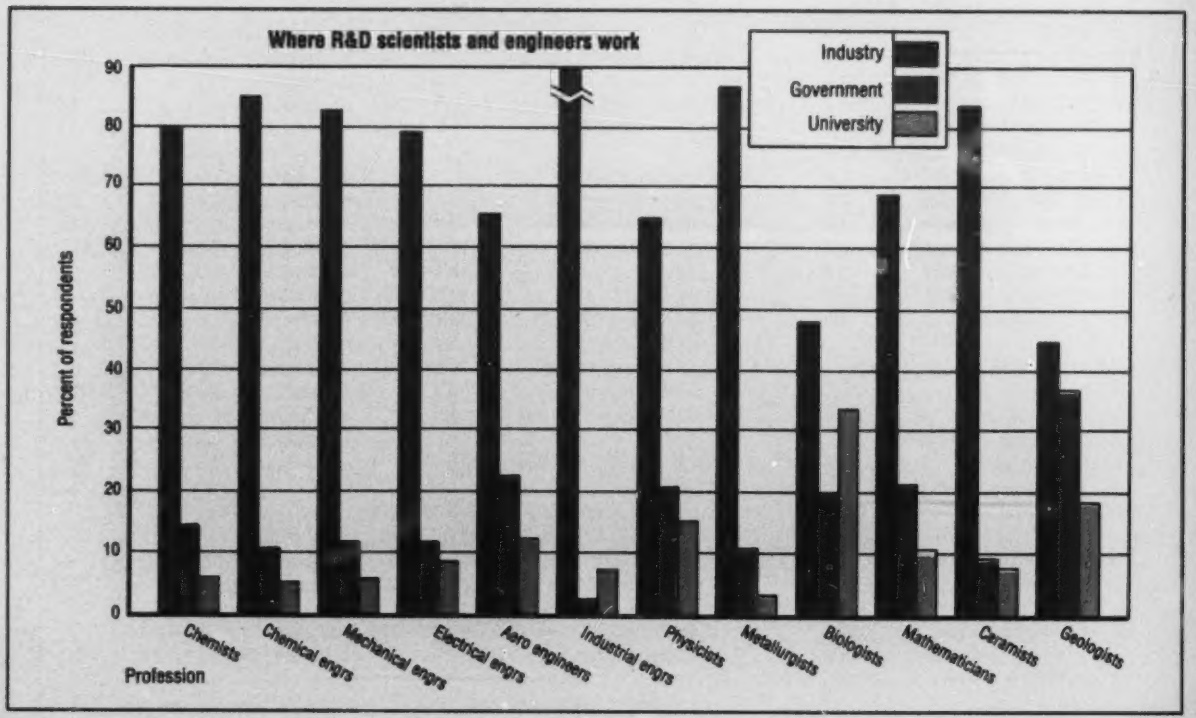
Using similar calculations with different allowances for earning years and expenses, we find that the present career value of a PhD over an MS is $1,000,000, give or take small change.

For the high school senior who is wondering about the value of college, the message should be clear. The net career benefit for BS over less-than-BS is more than three quarters of a million dollars ($778,000, in our calculations). And that comparison is being made to the median income of a non-BS worker in research and development, not to the stoop laborer or the chronically unemployed.

On this basis, the person who spends the four years necessary to get the BS can feel that he or she earns $194,000 per year while in college, and that doesn't even consider the other benefits that accompany a college degree.

Assume you already have a BS. What is it worth to go on for an MS? The answer is $703,000 over the years of a career, or the equivalent of $20,000 each working year.

At the extremes, the career benefit of a PhD over less-than-BS during a PhD's 35-year career is $2,480,000, or an added $70,800 per year when interest is included. The yearly difference in income for PhD over less-than-BS is $15,748, up 5% from last year's



$14,250. With interest accumulated over a 35-year career, the difference is $2.5 million.

Other comparisons and conclusions can be drawn from our survey information about salaries in relation to highest academic degree, as you will see in this table:

R&D salaries compared by academic degrees

Degree	Median salary 1987	Median salary 1986	Percent change	Annual difference* 1987	Annual difference* 1986	Difference increase (percent)
Doctorate	$50,396	$45,050	11.8	$6,449	$5,020	28.5
Master	43,947	40,030	9.8	4,313	4,970	−13.2
Bachelor	39,634	35,060	13.0	4,986	5,010	−0.5
<Bachelor	34,648	30,050	15.3			

*Difference above next lower degree

We mentioned earlier that these career benefit figures are based on medians, and that many PhDs will earn substantially more than the figures presented here. However, there are many who will earn less than these figures, and the vast majority of those are women.

Over the years since we began breaking out this industry profile data by sex, we have confirmed what many already believed: Women in R&D and QA get substantially less for the same work than men do.

Having said that, we must hasten to add that for many reasons women in these fields do not have the opportunities to become as well qualified as men do. The problem of women's low salaries in this industry has two parts, of which sex discrimination is just one.

The other part consists of the many reasons that women often do not have the same amount of experience, as much time with the present employer, or as much education as men do. The result is that, with few exceptions, the big salaries in R&D go to men with PhDs and substantial work experience.

It hardly is surprising, then, that the typical male R&D worker in industry is earning a median annual income of $44,636 compared to the female working in a university where her salary would be near $24,300.

So great is the difference by sex and workplace that it deserves special attention. To begin with, since industry passed government a few years ago as the top-paying workplace for R&D, the ranking in declining order of salary size has been industry, government, university.

Median salaries all R&D by workplace

	1980	1985	1987
Government	$29,733	$39,790	$42,200
Industry	28,354	40,980	43,877
University	25,685	34,950	38,621

Universities often have a high proportion of women working in R&D, a salary downer, but one might expect to see some buoyancy provided in the university salary levels by the fact that they also have a high proportion of PhDs. However, the latter does not counterbalance the former, and universities lag well behind industry and government in pay scales.

What is more, the discrimination and opportunity differences are so greatly tipped in favor of men, that the median annual salary for men in *universities* is $6,084 more than for women in *industry*, an increase in spread of more than 20% in the past year.

Women R&D workers in universities are no better off this year than last, in terms of median salary, while men in universities have improved their lot by $5,000, a 50% increase in the spread for men and women in universities.

Here are the figures; see for yourself:

R & D salaries compared by sex and workplace

	1987	1986	% gain
Men in industry	$44,636	$40,050	11.4
Men in government	43,239	40,040	8.0
Men in universities	40,521	35,040	15.6
Women in industry	34,437	30,070	14.5
Women in government	30,000	30,040	−0.1
Women in universities	24,318	25,100	−3.1

In this year's survey, the median annual salary for all males in R&D and QA is $44,061, up almost $6,000 in two years. The median for all women workers in R&D and QA is $32,736, up almost $4,000 in two years. The percentage gain is about the same, but it doesn't close any gaps.

Salary gains for women

Still, there are bright spots in the data for women. In recent years there have been some salary gains for them. This year's study shows that women did far better than men in terms of salary increases. While 60.8% of the men got no increase last year or an increase of less than 6%, only 50.3% of the women respondents fall into that category.

Nearly 50% of the women respondents reported a salary increase last year of 6% or more, while only 40% of the men did that well.

R&D salary increases by sex

Granted in	1985 (%) Male	1985 (%) Female	1986 (%) Male	1986 (%) Female
Amount				
None	11.6	7.7	16.5	12.8
Less than 2%	3.6	3.5	4.4	3.1
2 through 5%	37.6	31.3	39.6	34.4
6 through 9%	35.8	42.8	30.3	37.8
10 through 13%	8.3	8.9	6.0	6.9
14% or more	3.1	5.8	3.0	4.9

Of the women respondents this year, 60.1% report that they are earning more than $30,000 per year, down from 64.9% last year. Of the men, 88.2% are receiving annual salaries of $30,000 per year or more, up from 84.2% last year.

This and other information about comparable salaries m-f is reflected in an index chart which graphs number of respondents in each salary range in proportion to the number that would be in that range if male-female salary distribution were completely uniform.

Inasmuch as 91.7% of the respondents this year are male, then proportionate distribution would call for there to be 91.7% male and 8.3% female in every salary range. When that is the case, the index is 1.0. In

reality, there is such a disproportionate share of females in the lower salary ranges that it causes the bars for females to run off of that part of the chart.

Years of experience

On the chart showing years of experience by sex, it is easy to see that there is a goodly supply of experienced males in R&D, with 44.1% having more than 20 years' experience. Only 16.3% of the female respondents have that much experience, an obvious factor in the salary sweepstakes.

Why is it that women are so lacking in experience? There are many reasons, including interruption of a career to rear a family, changing jobs when a husband is transferred, and the instability of the lower steps on career ladders.

One of the big limiting factors for women is that a person cannot have long experience while being short on age. Of the female respondents in this year's study, 74.4% are 40 years of age or younger. Only 40.8% of the men are that young.

Understandably, few young females have PhDs. The percentage of females with PhDs is 19.7, down from 20.4 last year. For this year's male respondents, the percentage with PhDs is 28.8, also down this year (from 30.7).

Longevity with a firm tends to be rewarded as a normal consequence of periodic employment reviews or, occasionally, by default. This reward most often takes the form of increases in salary, and the correlation between time with the current employer and salary range is high.

The fact that 5.6% of the male respondents have been with their present employers for more than 30 years helps to explain their domination of the higher income brackets in our survey. This year, only one female respondent reported that she has been with her present employer for more than 30 years.

The many factors that mitigate against long-term employment for females lead us to expect a dominance of females in the short-term groups. And that is exactly what we find in this year's survey. Of this year's female respondents, 57.1% have been with their present employer less than 7 years. Only 37.1% of the males have been with their present employer less than 7 years.

This is a time of rapid change in the R&D industry. Salaries are only one thing that is changing. The male-female balance, demand for workers in one discipline or another, opportunities for high-paid staff members, value attributed to advanced degrees, and R&D's workplace (government, university, or industry) all are undergoing change in varying amounts and at differing rates.

The charts and tables with this article document many of those changes and provide details beyond what is presented in the text. R&D

Reader Response Panel

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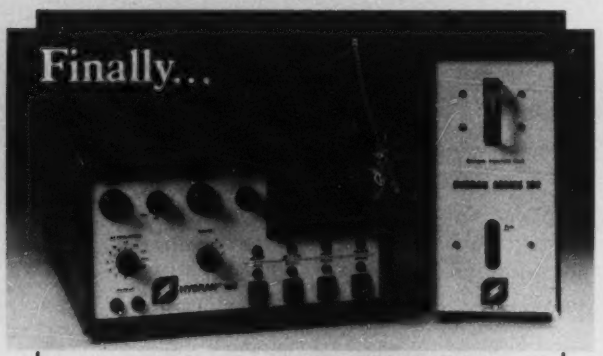
High **390** Medium **392** Low **394**



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Research & Development

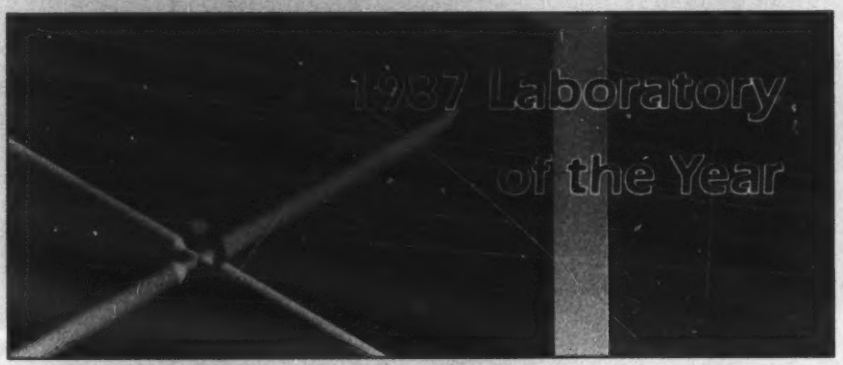
May 1987/Vol. 29/No. 5

SERVING THE $235-BILLION WORLDWIDE R&D INDUSTRY

Research & Development

The magazine with the R100 Awards

Expect the best in your new R&D lab. See p 78.



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ABOUT THE COVER

Designers and planners of *R&D's* 1987 Lab of the Year wanted to project a positive company image to the community, to encourage communication among the center's workers, to provide a safe environment that takes advantage of the site and enhances productivity, and to permit expansion and change to meet future needs.

Chevron's Ortho Research Center in Richmond, CA, is the Lab of the Year. The Metro Environmental Laboratories, operated by the Municipality of Metropolitan Seattle, WA, and Alberta Research Council's new lab in Edmonton, AB, are High Honors Laboratories.

An article describing the facilities begins on p 78.

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OPINION POLL RESULTS

Thermodynamic and spectral reference data most needed

THERMODYNAMIC and kinetic data got the highest vote in our survey of the needs of readers for reference data. Molecular spectral data (IR, Raman, NMR) came in a close second, both far ahead of atomic spectral data and mass spectral data.

The survey was conducted in cooperation with the Joint Committee on Atomic & Molecular Physical Data chaired by J.E. Griffiths of Bell Laboratories. The subject did not get a large response from readers. The 626 responses are a small fraction of our usual number.

Tabulation of the responses follows. Responses will be made available to the committee for additional processing.

1. Which kind of reference data is most important in your current job?
- a. Thermodynamic and kinetic data 29%
- b. Molecular spectral data (IR, Raman, NMR) 27
- c. Atomic spectral data 8
- d. Mass spectral data 10%
- e. Other 26

2. Do you prefer compilations of data available from:
- a. Computer-readable file ... 40%
- b. Hard-bound book 36
- c. Loose-leaf ... 21%
- d. Microfiche .. 3

3. What is your most pressing need for spectroscopic data?
- a. Organic compounds 37%
- b. Inorganic compounds 27
- c. Polymers 17%
- d. Other 14
- e. No need 5

4. What is your most pressing need for reference materials?
- a. Organic compounds 35%
- b. Inorganic compounds 28
- c. Polymers 20%
- d. Other 17

5. Where do you see the greatest need for improvement during the next decade?
- a. Standard reference materials 22%
- b. Evaluate reference compilations 33
- c. Instrumentation 24
- d. Quality of data accepted for publication 21

6. What is your most useful source for physical properties?
- a. J. Phys. & Chem. Reference Data 17%
- b. JANAF Thermochemical Tables 6
- c. NBS Chem. Thermodynamic Data Base 8
- d. Primary journals 36%
- e. Other 33

7. What is your most useful source for infrared spectral data?
- a. Coblentz Society IR Ref. spectra deskbook 2%
- b. Sadtler IR Spectra collections 23
- c. CRC Press Atlas of Spectra collections 12
- d. Aldrich IR Data compilation 13
- e. Internal data bases or other 27
- f. No need 23

8. What is your most useful data source for NMR data?
- a. Sadtler NMR data compilation 14%
- b. Aldrich NMR data compilation 12
- c. Varian NMR data collection 10
- d. NIH/EPA data compilation 3
- e. Internal data sources or other 26
- f. No need 35

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New materials and their uses

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New materials—Photomicrograph by P.E. Danielson, Teledyne Wah Chang, Albany, OR, from Carl Zeiss Inc. shows cross section of modified jelly-roll conductor after heat treatment diffuses Sn through copper matrix to form superconducting Nb_3Sn. Articles about other new materials begin on pages 54 and 62.

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75 **Turbopumps make better TV tubes:** D. Goetz, G. Schaefer, and J. Rufus, Leybold-Heraeus; replacing diffusion pumps improves productivity.

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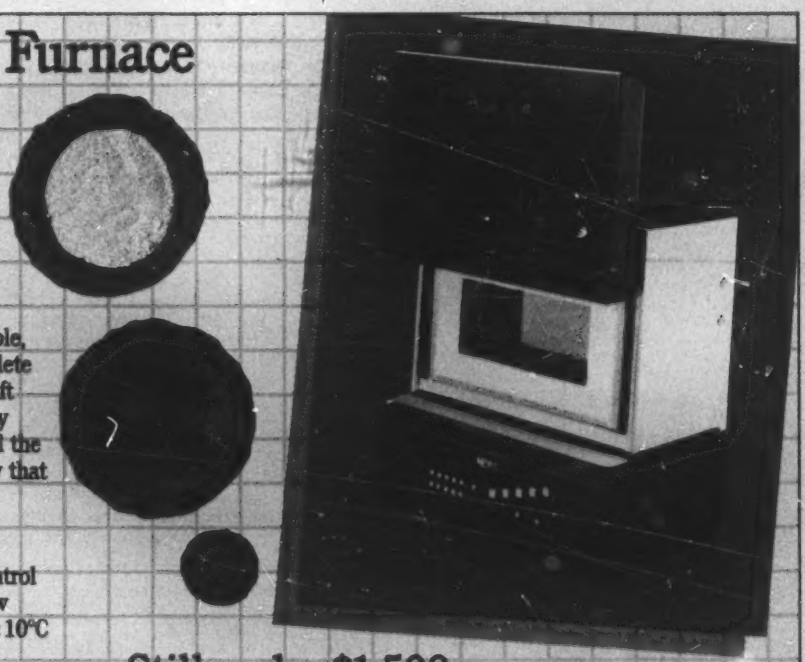

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Soon we all may drive plastic cars

Auto manufacturers and suppliers will share risks and rewards as they substitute composites and reinforced plastics for steel.

Edward M. Hogan
Monkman-Rumsey

THE REPLACEMENT of steel in automobile frames and bodies offers one of the largest opportunities for the application of reinforced plastics and composites. The size of the opportunity is staggering: more than a billion lb/yr for the bodies of standard American sedans alone by the year 2000.

Likewise, the sizes of the incentives and the rewards are staggering. But so are the possible obstacles.

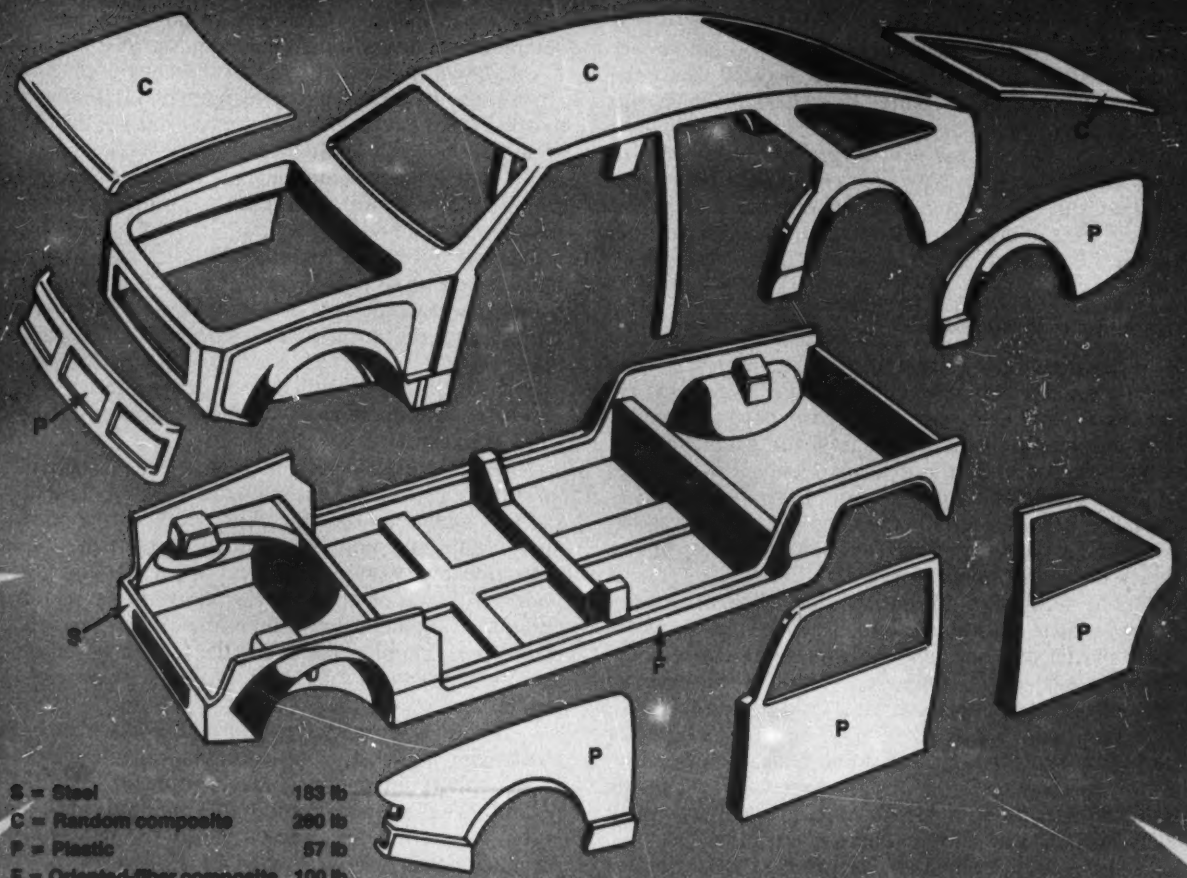
Still, automobile manufacturers are becoming convinced that change is inevitable—indeed, imperative—if the U.S. auto industry is to remain an active competitor in the personal transportation market. These statements are some of the conclusions of a definitive study recently completed by Monkman-Rumsey, a Wilmington, DE, consulting firm that specializes in market studies, technology assessment, and venture management.

Plastics in cars

The driving forces for these changes are competition and economics. In addition to worldwide pressure for product differentiation and frequent styling changes, U.S. automakers are under severe pressure to reduce costs. The chief threat here, of course, is the likelihood of a $2,000 to $3,000 differential in manufacturing cost, compared to automobiles made in Japan.

Because of these pressures, U.S. auto manufacturers are beginning to accept the "plastic car" as the route to the future. The higher costs of plastic materials, compared to the cost of steel, are more than offset by significantly reduced capital investment for tooling, economies in fabrication and assembly, more-efficient

PONTIAC FIERO plastic rear quarter panel resists dents, keeps a "showroom" appearance, and retains physical properties at high and low temperatures (DuPont photo).



S = Steel	183 lb
C = Random composite	260 lb
P = Plastic	57 lb
F = Oriented-fiber composite	100 lb
Total weight, body-in-white (projected concept, Type III)	600 lb

PLASTIC PARTS will replace steel in the structure of an auto "body-in-white," the components of frame and body panels just before painting. Drawing from "The Use of Composites and Plastics for Bodies-in-White in U.S. Passenger Cars, 1990-2000," copyright 1986 Monkman-Rumsey.

deployment of workers, and reduced labor costs.

An added incentive for change is the promise of design freedom, allowing the use of more-complicated and more-complex curves and shapes, along with the relative ease of making rapid design and styling changes.

From the auto owner's point of view, the ability of composites and reinforced plastics to recover from impact minimizes the importance of minor surface damage, such as "dings" and so-called stone bruises. With plastics, these effects will not be as badly disfiguring as they are on a steel-bodied car.

Moreover, plastics do not rust like steel. Since few initial purchasers of automobiles keep their vehicles long enough for freedom from structural rust to have a significant effect on resale value, this advantage may not be particularly important for original-equipment manufacturers (OEMs).

Issues to be resolved

The foremost obstacle to the use of large amounts of plastics in automobile structures is the need for unprecedented cooperation in problem solving and in risk/reward sharing by everyone concerned with auto manufacture. These people include raw-materials producers, machine builders, plastics converters, and OEMs.

Critical technical issues that need to be resolved include the following:

- ☐ Establishment of tests and specifications to ensure performance in production and service.
- ☐ Development of tools capable of fabricating large, complex components with forming times of one minute ± a few seconds.
- ☐ Development of new assembly technology and machinery.
- ☐ Development of systems to recycle and/or dispose of plastic components and cars after they no longer are useful.

These issues will put heavy demands on the R&D capabilities of the entire industry. They also will influence materials selection and the trade-offs involved in determining the "winners" in this major new market for reinforced plastics.

From a technical standpoint, the production of plastic cars is feasible today. This fact has been demonstrated by the limited production of street machines such as the Lotus series and the De Lorean, and by standard-production vehicles—made in progressively larger production runs—from the Corvette, beginning

in the early 1950s to the Fiero in late 1983.

The De Lorean's cosmetic stainless-steel veneer concealed an entire body structure of glass-reinforced polyester. The "space-frame" Fiero design, which separated the visible surface panels from the load-bearing steel cage, opened the way to previously unheard-of versatility in styling. Now, restyling could be accomplished simply by exchanging the reinforced-plastic panels. Retooling for such restyling would cost only about a fifth as much as retooling for a line of steel-skinned cars.

Evolution of plastic autos

In our study we drew upon this experience, then used computer-aided design to examine various material/design combinations to compare performance-to-cost considerations. The results of the study were reviewed with 130 automotive engineers, raw-material suppliers, machinery makers, and component fabricators. The report's authors then applied their own technical and market experience to analyze the data and to reach the report's conclusions.

The study showed that the development of reinforced-plastic automobile bodies probably will evolve from plastic skins for "sporty" cars to the entire body-in-white (structural components and exterior panels) for full-sized family sedans, vans, and pickup trucks.

We used a full-sized "family" sedan as a basis for the study's calculations and predictions since these sedans represent 28% of all passenger cars sold in the U.S. Sedans account for an even greater portion of U.S. automakers' sales revenues and profits.

As a result of our study, we predict that during the next 15 to 20 years the use of plastics and composites in auto bodies will evolve through three design/engineering phases:

☐ By 1990, lightly loaded fixed and movable skin panels, requiring Class A surfaces, can be affixed over a load-carrying frame. At the present time, the Fiero is the best example of such an approach.

☐ By 1995, manufacture of fixed horizontal composite surfaces that require stiffness to withstand torsion and bending loads in the cab roof and floor, as well as Class A finishes, should be possible. The research version of the Audi 5000S sedan demonstrates this concept today.

☐ By about 2000, or perhaps 2005, we will have structural composites for the body pan, the front crash structure, the rear suspension, and the trunk floor, covered by Class A plastic surfaces. No steel will be used, except possibly for the engine-suspension mount. The De Lorean cars were built in this manner.

Solving of problems

A key requirement for making plastic autos successful is parts consolidation. For example, one body design has only 19 components, compared with several hundred parts in steel bodies used today. Assembly can be accomplished in less than 1.5 man-hours of labor, compared with 6 man-hours for the steel designs.

Probably, consolidation will be carried to an even greater extent: Wire ducts, fluid containers, and other details that require time-consuming hand assembly in present designs can be molded into structural parts.

Technically, machinery for processing large plastic parts at high speeds is feasible now, but continuing development presents some challenging problems. Such development is inherently riskier than developing new engineering materials, and investment capital is harder to obtain. For example, there are no "market-development quantities" for a 5,000-ton press. It is easy to understand that machine builders are reluctant to commit major funds without a guarantee of a market for the products developed.

Other problems include the long development time—often as long as seven years for a single machine—the machine-tool industry's already strained capacity, and the scarcity of some needed technical knowledge and expertise. Few mold shops, for example, have craftsmen skilled enough to produce large molds to close tolerances with the surfaces needed for Class A finishes.

In addition, the lack of industry-wide standards for auto-body panels spotlights the need for standardization, adequate specifications, and testing procedures. Materials suppliers' standard tests, such as heat deflection temperature and Izod impact strength, are poor predictors of actual performance in paint ovens and under impact at low temperatures. Yet, no OEM or materials supplier has taken the lead in developing realistic procedures for characterizing performance of new reinforced plastics.

The development of the required tests will be both challenging and costly, and coordination among materials suppliers and quality control people for parts manufacturers will require considerable time. One problem is that, when they are used on plastic panels, some of the paints that originally were developed for use on metals can cause localized crazing that can reduce the impact strength of the parts to half its original value.

Efforts to develop industry-acceptable specifications and standard test procedures offer solid potential for financial reward in at least two areas:

☐ Designers go where data bases exist. There is potential reward in emulating the aerospace industry. In this area, standard methods and data bases available to designers, fabricators, and decision makers have handsomely repaid the materials suppliers' multimillion-dollar development efforts.

☐ The company that develops a test accepted by auto designers has the opportunity to define materials standards for that application. Any industry-wide tests will inevitably favor some materials and discriminate

Material projections for standard car bodies (millions of lb/yr)

Material	1985	1990	1995	2000	2005
Steel	1,714	1,734	1,298	894	823
Random composites	0	159	433	906	743
Plastics (filled and unfilled)	0	67	188	182	163
Oriented-fiber composites	0	0	149	249	286
Total	1,714	1,960	2,068	1,930	1,715
Total composites and plastics	0	226	782	1,036	1,192

against others because of the variety of mechanisms by which composite materials respond to complex stresses inherent in any test that realistically represents performance environments. In fact, one purpose of such tests is to discriminate against materials that cannot perform adequately in a given application.

A full service performance data base (excluding paint-over performance) must cover static, fatigue, creep, and impact behavior in realistic shapes at temperatures ranging from −20 F to +150 F, in controlled relative humidity from 5 to 95%, and at impact velocities as high as 55 m/s.

Materials development and handling

The manufacture of large, complex shapes needed for significant parts consolidation at a rate sufficient to feed a 50- to 70-car/hr production line will push processing technology and equipment to the limits of their present capabilities.

For structural parts, compression molding can handle the sizes needed. Still, presses required for major chassis molding will be in the 5,000-ton class. Extensive new investment will be needed here. On a laboratory scale, a 60-sec cycle for auto parts has been demonstrated; the process should be in commercial production by 1990.

Reaction injection molding (RIM) can handle large-sized parts, but only with 2-min. cycle times—4 min. if the parts have to be postcured. Structural RIM and high-speed resin-transfer molding (injecting reactive oligomers around prepositioned glass mats in a sealed mold) are processes that are under extensive development. For these processing techniques, commercial availability dates are uncertain, and it is not known whether the techniques can produce a Class A finish.

Ordinary injection molding has produced Class A finishes on moderate-sized panels (the Fiero quarter panel, for example). At present, however, it is questionable whether the process can be scaled up for the high-speed production of large parts.

At the same time, materials development will be affected by the relative success in resolving other issues. Classes of polymers that can do the job already exist. Any new materials that may be needed probably will come from the development of alloying technology and from interpenetrating-network techniques. Costs at all stages of the development will be important considerations.

Recycling and disposal of plastics

Until recently, neither the automotive industry nor the Federal government has acknowledged the problem of either recycling or disposal of auto bodies containing large amounts of plastics and composites.

To the existing automobile-dismantling and recycling industry, plastics and composites have negative economic value. Any additional reduction in or elimination of economic incentives to collect and recycle worn-out vehicles, or any new regulations about hazardous waste in landfills, could lead to the abandonment of more junked cars—and even more government regulation of manufacturing.

To address the plastics-disposal issue, the Institute of Scrap Iron & Steel (ISIS) has funded two projects.

A recycling study has found that molding of products from scrap is expensive. The only practical products are those that can tolerate a mixture of thermoset and thermoplastic materials. The presence of metal scrap and other contaminants rules out processes such as injection molding. To date, products from recycled plastics are confined to fence posts and similar nonprecision, low-value items.

A second project, involving the burning of shredder residues as fuel, is more promising. Shredder residue from early 1970s cars has a fuel value of 5,000 BTU/lb in utility steam boilers, comparable with 10,000 to 12,000 BTU/lb for coal. Adding junk tires raises the fuel value to 7,000 to 8,000 BTU/lb. Even at this condition, the process still complies with existing air-pollution regulations.

The fuel value may change as types of polymers change and as the use of noncombustible fillers increases. Airborne residue from carbon fiber is a possible hazard because of the potential for short-circuiting electrical equipment.

In any case, should the driving force for auto-body recycling change from the present basis in scrap-metal values to energy recovery, the entire character of the recovery/recycling business would change.

The plastics-disposal issue will not become critical until about the turn of the century, when 1989 and 1990 models reach recycling age in significant numbers. There still is time for an industry response, either at the design stage or by the creation of incentives and mechanisms to ensure collection and disposal of the plastic bodies from worn-out cars.

In Detroit, auto designers and manufacturers are beginning to realize that revolutionary changes are needed to achieve major cost savings that can meet foreign competition. One of the most promising approaches is the use of reinforced plastics and composites as structural materials.

As we have noted earlier, overcoming of the many technical and economic obstacles will require extensive cooperation and risk-sharing among auto manufacturers and their suppliers. The rewards will be immense. The R&D community will have to be in the forefront of the effort. R&D

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C1850-6
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Research & Development

SEPTEMBER 1987

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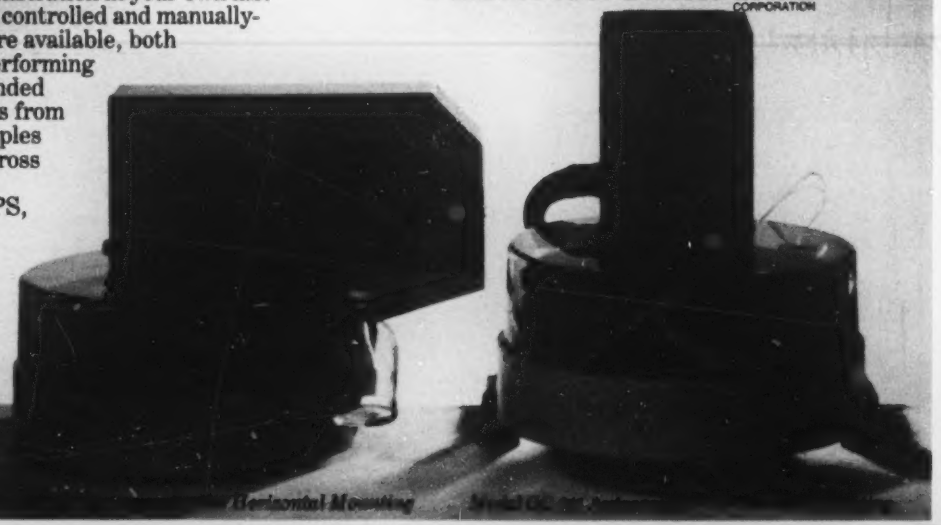

CIRCLE **127** ON INQUIRY CARD

OPINION POLL RESULTS

Dollar signs get in the way of long-term profits

TWO out of three workers in research and development know of specific instances when projects which might have succeeded in the long term were cut short or avoided because continuing them could hurt quarterly profits. More than three out of four feel under pressure to keep quarterly profits up.

That this is a serious problem for the U.S. has been suggested in this issue's Editorial and others. Readers of this magazine were asked to respond to questions on this subject, and nearly 650 of them did. Comments on the results of this survey appear in the Editorial.

Complete results of the survey follow:

1. *Are you aware of pressures in your firm to keep all quarterly profits up?*
   a. Yes 78% b. No 22%

2. *Do you feel that when there are such pressures product development automatically suffers?*
   a. Yes 65% b. No 35%

3. *Have you known of specific instances when projects which might have succeeded in the long term were cut short or avoided because they could hurt quarterly profits?*
   a. Yes 63% b. No 37%

4. *Is your organization's R&D done as an integral part of the company or corporate effort?*
   a. Yes 71% b. No 18%
   c. Don't know 11

5. *Does your organization have long-term product development programs of a year or more?*
   a. None 13%
   b. One 9
   c. Several 55
   d. Many 18
   e. Don't know 5

6. *Do you think that separating R&D fiscally from the rest of the company could help quarterly profit problems?*
   a. Yes 58% b. No 42%

7. *Would you consider buying stock dedicated to a specific product development project?*
   a. Yes 58% b. No 42%

8. *Do you think that many investors would consider buying stock dedicated to a specific product development project?*
   a. Yes 53% b. No 47%

9. *Would you consider buying stock in a company dedicated to product development only (no manufacturing or marketing)?*
   a. Yes 56% b. No 44%

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